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EFFECTS OF LIMNOLOGICAL FACTORS ON UPTAKE
OF ¹³⁷Cs FALLOUT BY FISH

Niles R. Kevern

Final Report

COO-1795-3

to the

United States Atomic Energy Commission

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Effects of Limnological Factors on Uptake
of ^{137}Cs Fallout by Fish

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Introduction

This paper is a final report on research conducted between June, 1968, and April, 1971. Details and discussion of results have been presented in progress reports COO-1795-1 and COO-1795-2 and in Supplements to this report, COO-1795-6 and COO-1795-7. Two papers, COO-1795-4 and COO-1795-5, have been presented at a national symposium and presumably will appear in the proceedings. Therefore, this report is a summary of the original objectives and the significant results and conclusions.

Original Objectives

The project was designed to study the factors suspected of influencing the accumulation of ^{137}Cs by fish in the natural environment. Specifically the objectives were, (1) to determine which water quality parameters were most important in controlling uptake by fish, (2) to determine how these factors operate, (3) to determine whether trophic position was a factor that influenced the accumulation and, finally (4) to develop a predictive model for the uptake of ^{137}Cs by fish when inputs of ^{137}Cs to the water are given. The objectives have been reasonably achieved.

Methods

One of the important aspects of the study was to measure stable Cs concentrations in lake water and thereby use the specific activity concept as a basis for developing the predictive model. Every reported method was thoroughly explored and tested. Several new methods of concentrating Cs from water also were attempted. Measurement of the stable Cs in water still was not feasible. The methods attempted are given in detail in COO-1795-7. Concentrations of Cs in lake water ultimately were calculated from specific activities of fish and ^{137}Cs in water as follows:

$$\frac{^{137}\text{Cs}}{\text{stable Cs}} \text{ in fish: } \frac{^{137}\text{Cs}}{x} \text{ in water}$$

Fish samples were completely digested in concentrated nitric acid and the subsequent solution treated with ammonium molybdophosphate (AMP) resin to collect the cesium isotopes. The AMP residue was dissolved in NaOH and extracted with sodium tetraphenylboron (TPB). Activities of ^{137}Cs in fish were determined by gamma scintillation counting of the AMP residue. Stable Cs analyses were performed on the TPB extracts using flame emission spectrophotometry.

Water concentrations of ^{137}Cs were accomplished by preconcentration on cobalt ferrocyanide resins (KCFC) and subsequent analysis by gamma scintillation.

Results and Discussion

Six lakes were chosen for the study. Water parameters studied were specific conductance, ^{137}Cs , stable Cs, K and Na. Largemouth bass (Micropterus salmoides) were the fish selected. For the lake comparison, only age three fish were used. Regression analysis was used to determine the relationship

between ^{137}Cs uptake and the water parameters. Analysis of variance indicated that the uptake by bass was significantly different between the lakes.

Table 1 shows the results of the simple linear regressions (simple R^2) and the results of the multiple regression analysis. Strong negative correlations were shown individually for specific conductance (- 0.8716), Cs (- 0.7605), and Na (-0.6218). A slight negative correlation was indicated with K (- 0.0549) and a positive correlation was indicated for ^{137}Cs (0.3298). The results changed considerably with multiple correlation and least squares deletion. The influence of Na and specific conductance was deleted. The calculated regression equation for the six Michigan lakes is:

$$^{137}\text{Cs}_{\text{Bass}} \text{ pCi/gm wet wt} = 1.5912 + 6.8118 (^{137}\text{Cs}_{\text{pCi/liter}}) - 0.0557 (\text{Cs}_{\text{ng/liter}}) - 0.3838 (\text{K}_{\text{mg/liter}}).$$

The equation satisfies objectives one, two and four. The parameters influencing ^{137}Cs uptake by bass are water concentrations of ^{137}Cs , stable Cs and K. The factors operate in a positive fashion for ^{137}Cs in water and negatively for stable Cs and K. The equation serves as a predictive model specifically for the six lakes studied (described in COO-1795-4, -5, and -6) and for midwestern lakes in a very general fashion. It should be noted that mathematically it is possible to delete ^{137}Cs from the right side of the equation and still have a result on the left side of the equation. This, of course, is not true in practice. It is impossible to have uptake by fish without having the radioisotope in the water.

Studies of uptake of ^{137}Cs in a bass population in a single lake (COO-1795-5) revealed no influence by sex. Size, by weight, revealed a significant effect with the ^{137}Cs concentration increasing with fish weight

Table 1. Linear correlation coefficients between ^{137}Cs activities of bass and lake parameters.

Dependent Variable (Y)		Independent Variables (X)				
^{137}Cs (Bass)		^{137}Cs	K	Cs	Sp. Cond.	Na
Simple R^2		0.3298	-0.0549	-0.7605	-0.8716	-0.6218
Multiple R^2	(X_1-X_5)					1.0000
	(X_1-X_4)				0.9999	
	(X_1-X_3)			0.9999		
	(X_1-X_2)		0.9352			
Estimated Regression						
Equation:						
$^{137}\text{Cs} = 1.5912 + 6.8118 (^{137}\text{Cs}) - 0.0557 (\text{Cs}) - 0.3838 (\text{K})$						

up to a limit of about 1100 gms and decreasing with weight beyond 1100 gms. There appeared to be no correlation between ^{137}Cs activity in the fish and precipitation; however, bass concentration of ^{137}Cs was highest in the spring.

Evaluation of Progress

The project has contributed to our understanding of the biogeochemical cycling of Cs in freshwater lakes. Data are presented that identify and quantify the parameters that are most important in influencing uptake of ^{137}Cs by fish. These are, in order of their importance, concentrations in water of ^{137}Cs , K and stable Cs; the latter two having negative correlations. An equation has been developed that can be used to predict uptake by fish when fallout or accidental inputs of ^{137}Cs to the water are given. The study has identified areas for further research effort. One apparent area is the need for development of a good sensitive method for stable cesium analysis. Levels in freshwater systems are roughly 20-40 ppt. Development of a method sensitive even at the low ppb range would be feasible using other methods to concentrate water samples. A second area in need of study is the concept of specific activity. While this study was designed to support this concept, the failure to develop the capability for stable cesium analyses for water samples also defeated collection of data to support the concept. It is possible that a project could obtain this information in small, controlled ponds by adding sufficient stable cesium to the ponds to enable analysis by existing methods. The development of a more sensitive method would allow research in lakes with natural cesium levels.

This project strongly suggests that additional work should be directed at the influence of potassium levels on uptake of ^{137}Cs by fish. Research should build upon the data collected during this project. This might be

done by selecting a larger series of lakes, 15-20 in number, with the selection designed to develop a good range of potassium concentrations. Multiple regression techniques could be used to analyze the data.

In summary, this project has identified water concentrations of stable Cs, K and ^{137}Cs as parameters influencing the uptake of ^{137}Cs fallout by fish. An equation is developed that allows prediction of uptake when the above parameters are measured or theorized. Parameters operating within a fish population also have been studied and those having an influence identified. Finally, ideas for further research have been suggested.

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